Overview Task 1.2: Hadron decays

HaSp-STRONG2020 Workshop

14-16 September 2021

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Supported by EU Horizon 2020 research and innovation programme, STRONG-2020 project, under grant agreement No 824093

Task 1.2: Hadron decays

General description

We will investigate decays of heavy hadrons, looking for particular interacting hadron pairs in the final state that might produce resonant states. Using Dalitz-plot based methods, EFT and dispersive techniques, we shall also explore issues such as the exotic nature of resonances, isospin or CP violations.

Hadron decays are essential properties of hadrons

The decays can discriminate between different pictures to understand the nature of the states

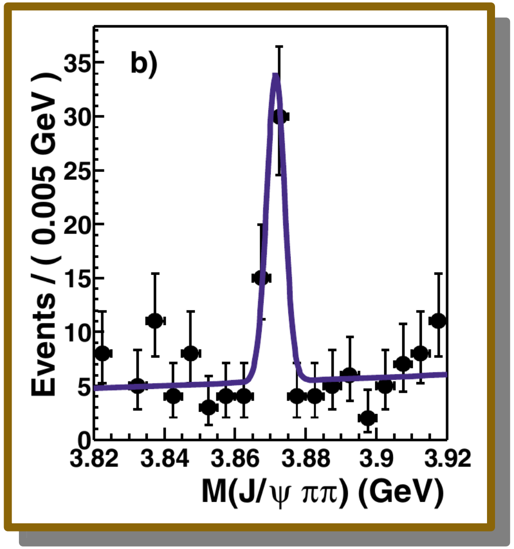
Deviations from expectations due to well known symmetries can give signatures of new physics

The X(3872) now $\chi_{c1}(3872)$

Mass very close to the $D^{*0}\bar{D}^0$

$$B \equiv m_{X(3872)} - m_{D^{*0}} - m_{\bar{D}^0} = 1.1^{+0.6+0.1}_{-0.4-0.3}\ \text{MeV}$$
$$= (0.00 \pm 0.18)\ \text{MeV}$$

Belle 2003



From a ω Belle arXiv: hep-ex/0505037

$$\frac{\mathcal{B}(X(3872) \to \pi^+\pi^-\pi^0 J/\psi)}{\mathcal{B}(X(3872) \to \pi^+\pi^- J/\psi)} = 1.0 \pm 0.4(\text{stat}) \pm 0.3(\text{syst})$$

From a ρ^0 CDF Phys. Rev. Lett. 96, 102002

Isospin breaking scale

$$m_{D^{*+}} + m_{D^-} - m_{D^{*0}} - m_{\bar{D}^0} = 8.2 \pm 0.1\ \text{MeV} \gg B$$

$$\frac{m_{D^+} - m_{D^0}}{m_{D^+} + m_{D^0}} \sim 0.13\%$$

$$\frac{m_{D^{*+}} - m_{D^{*0}}}{m_{D^{*+}} + m_{D^{*0}}} \sim 0.08\%$$

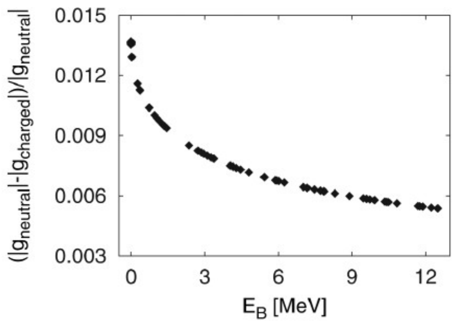
Isospin violation

D. Gamermann and E. Oset, Phys. Rev. D 80, 014003 (2009). QFT treatment

Less than 1% isospin violation

$$g_{D^+D^{*-}} = 2982$$
$$g_{D^0\bar{D}^{*0}} = 3005$$

Interpreted as probabilities →



Small isospin breaking effect $\mathcal{R}_{\rho/\omega} \sim 3.2\%$

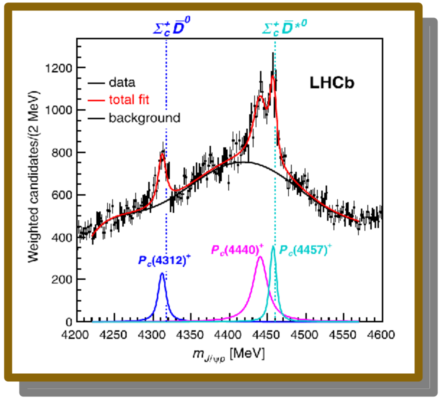
$$\frac{\mathcal{B}(X(3872) \to \pi\pi J/\psi)}{\mathcal{B}(X(3872) \to \pi\pi\pi J/\psi)} = \mathcal{R}_{\rho/\omega} \frac{\int_0^\infty q\mathcal{S}(s, m_\rho, \Gamma_\rho)\theta(m_X - m_{J/\psi} - \sqrt{s})ds}{\int_0^\infty q\mathcal{S}(s, m_\omega, \Gamma_\omega)\theta(m_X - m_{J/\psi} - \sqrt{s})ds} \times \frac{\mathcal{B}_\rho}{\mathcal{B}_\omega}$$

Final result compatible with experimental data

Phase space effect due to large differences on the widths

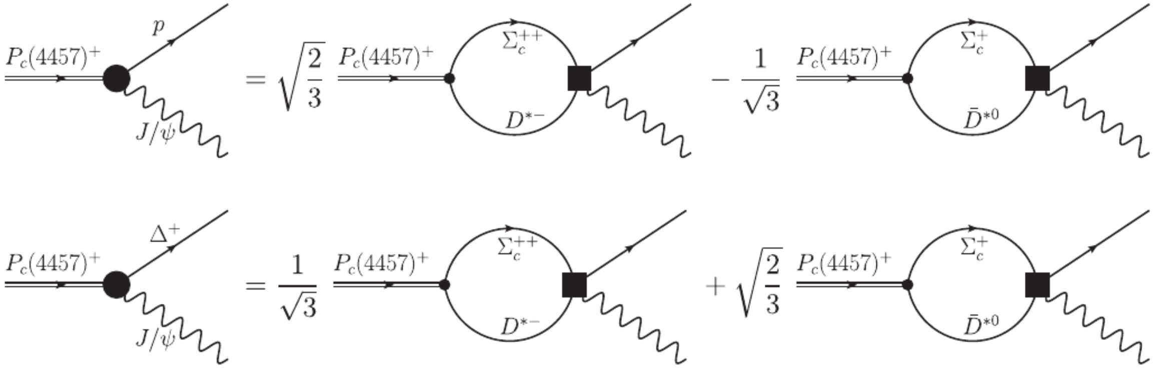
Pentaquarks

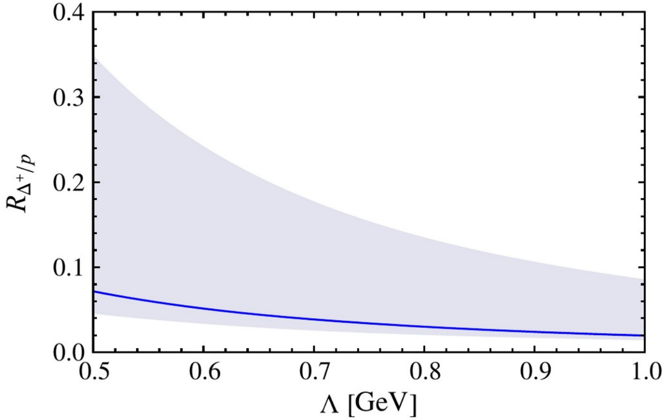
$$M_{P_c(4457)^+} = 4457.3 \pm 0.6^{+4.1}_{-1.7}$$
$$\Gamma_{P_c(4457)^+} = 6.4 \pm 2.0^{+5.7}_{-1.9}$$
$$M_{\Sigma_c^+} + M_{\bar{D}^{*0}} = 4459.8 \pm 0.4\,\text{MeV} \Rightarrow B_1 = 2.5^{+1.8}_{-4.2}\,\text{MeV}$$
$$M_{\Sigma_c^{++}} + M_{D^{*-}} = 4464.23 \pm 0.15\,\text{MeV} \Rightarrow B_2 = 6.9^{+1.8}_{-4.1}\,\text{MeV}$$



In analogy to the X(3872)

$$R_{\Delta^+/p} = \frac{|\mathcal{B}(P_c(4457)^+ \to J/\psi\Delta^+)|}{|\mathcal{B}(P_c(4457)^+ \to J/\psi p)|}$$





F.-K. Guo et al., Phys. Rev. D 99, 091501 (2019).

Uncertainties coming from pentaquark mass

The X(3872) binding energy

F.-K. Guo, Phys. Rev. Lett. 122, 202002 (2019)

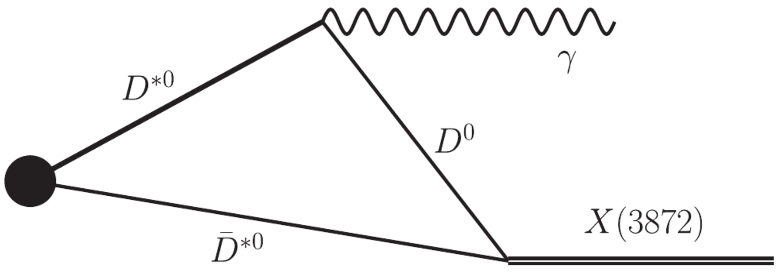
Proposal to measured the X(3872) binding energy with the triangle singularity

Prove the long range properties of the X(3872)

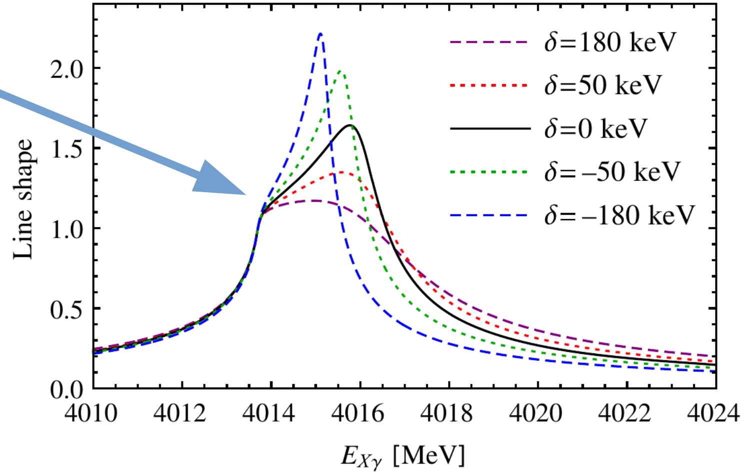
$$I(E_{X\gamma}) = \frac{1}{E_\gamma}\left[\arctan\left(\frac{c_2 - c_1}{2b\sqrt{c_1}}\right) + \arctan\left(\frac{c_1 - c_2 + 2b^2}{2b\sqrt{c_2 - b^2}}\right)\right]$$

$$E^{TS}_{X\gamma} = 2m_{D^{*0}} + \frac{x^2}{2m_{D^0}} + \mathcal{O}\left(\frac{x^3}{m^2_{D^0}}\right)$$

$$x = m_{D^{*0}} - m_{D^0} - 2\sqrt{-m_{D^0}\delta} + \delta$$



Cusp fixed



Contributions (first 18 months):

http://web.ge.infn.it/jstrong2020/index.php/task-1-precision/task-1-2

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Physics Letters B 807 (2020) 135534

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Physics Letters B

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π^0-η-η' mixing from $V \to P\gamma$ and $P \to V\gamma$ decays

Rafel Escribano [a,b], Emilio Royo [a,*]

- SU(3) flavor symmetry breaking mix singlet and octet states

- The u and d mass difference and QED effects induced isospin symmetry breaking effects and mix isospin 0 and 1 states

$$\mathscr{L}_{VP\gamma} = g_e \epsilon_{\mu\nu\alpha\beta} \partial^\mu A^\nu \mathrm{Tr}[Q\,(\partial^\alpha V^\beta P + P \partial^\alpha V^\beta)]$$

$$\begin{pmatrix} \pi^0 \\ \eta \\ \eta' \end{pmatrix} = \begin{pmatrix} 1 & \epsilon_{12} & \epsilon_{13} \\ -\epsilon_{12} c\phi_{23} + \epsilon_{13} s\phi_{23} & c\phi_{23} & -s\phi_{23} \\ -\epsilon_{13} c\phi_{23} - \epsilon_{12} s\phi_{23} & s\phi_{23} & c\phi_{23} \end{pmatrix} \begin{pmatrix} \pi_3 \\ \eta_{NS} \\ \eta_S \end{pmatrix}$$

$$\begin{pmatrix} \epsilon_{12} \\ \epsilon_{13} \end{pmatrix} = \begin{pmatrix} c\phi_P & s\phi_P \\ -s\phi_P & c\phi_P \end{pmatrix} \begin{pmatrix} \epsilon \\ \epsilon' \end{pmatrix}$$

Table 1
Comparison between estimations for the seven free parameters from the model presented in Ref. [6], using the PDG 2000 and the most up-to-date experimental data.

Parameter	Estimation from [6]	Current Estimation
g	0.70 ± 0.02 GeV^{-1}	0.70 ± 0.01 GeV^{-1}
$\frac{m_s}{\bar{m}}$	1.24 ± 0.07	1.17 ± 0.06
ϕ_P	$(37.7 \pm 2.4)^\circ$	$(41.4 \pm 0.5)^\circ$
ϕ_V	$(3.4 \pm 0.2)^\circ$	$(3.3 \pm 0.1)^\circ$
z_{NS}	0.91 ± 0.05	0.84 ± 0.02
z_S	0.89 ± 0.07	0.76 ± 0.04
z_K	0.91 ± 0.04	0.89 ± 0.03
χ^2_{min}/d.o.f.	0.7	4.6

$$|\eta\rangle = \cos\phi_P\,|\eta_{NS}\rangle - \sin\phi_P\,|\eta_S\rangle$$

$$|\eta'\rangle = \sin\phi_P\,|\eta_{NS}\rangle + \cos\phi_P\,|\eta_S\rangle$$

$$|\pi^0\rangle = |\pi_3\rangle + \epsilon\,|\eta\rangle + \epsilon'\,|\eta'\rangle$$

Physics Letters B 807 (2020) 135534

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$$\epsilon = \epsilon_{\pi\eta} = (0.1 \pm 0.9)\%$$
$$\epsilon' = \epsilon_{\pi\eta'} = (3.4 \pm 0.9)\%$$

π^0-η-η' mixing from $V \to P\gamma$ and $P \to V\gamma$ decays

Rafel Escribano [a,b], Emilio Royo [a,*]

- *ε' is incompatible with zero*
- *π^0-η_8 mixing is smaller than π^0-η_0. One would expect the opposite*
- *Fit with ε=ε'=0 is worse*
- *Most of the parameters are almost the same in different fits*

Table 2
Summary of fitted values for the Fit 1, Fit 2, Fit 3, Fit 4 and Fit 5, corresponding to Eqs. (13), (14), (15), (16), and (17), respectively.

Parameter	Fit 1	Fit 2	Fit 3	Fit 4	Fit 5
g (GeV^{-1})	0.69 ± 0.01	0.69 ± 0.01	0.69 ± 0.01	0.70 ± 0.01	0.69 ± 0.01
ϵ_{12}	$(2.3 \pm 1.0)\%$	$(2.4 \pm 1.0)\%$	-	-	$(2.4 \pm 1.0)\%$
ϵ_{13}	$(2.5 \pm 0.9)\%$	$(2.5 \pm 0.9)\%$	-	-	$(2.5 \pm 0.9)\%$
ϕ_{23} (°)	41.5 ± 0.5	41.5 ± 0.05	41.4 ± 0.5	41.4 ± 0.5	41.5 ± 0.5
ϕ_V (°)	4.0 ± 0.2	4.0 ± 0.2	3.1 ± 0.1	3.2 ± 0.1	4.0 ± 0.2
$m_s/\overline{m}$	-	1.17 ± 0.06	1.17 ± 0.06	1.17 ± 0.06	-
$z_S\overline{m}/m_s$	0.65 ± 0.01	-	-	-	0.65 ± 0.01
z_{NS}	0.89 ± 0.03	0.89 ± 0.03	0.86 ± 0.02	0.85 ± 0.02	0.89 ± 0.03
z_+	0.95 ± 0.05	-	-	-	-
z_S	-	0.77 ± 0.04	0.77 ± 0.04	0.77 ± 0.04	-
z_K	-	0.90 ± 0.03	0.90 ± 0.03	0.90 ± 0.03	-
z'_{K^0}	1.01 ± 0.04	-	-	-	-
z'_{K^+}	0.76 ± 0.04	-	-	-	-
χ^2_{min}/d.o.f.	2.3	1.9	4.4	4.8	1.9

Table 3
Comparison between the experimental decay widths Γ_{exp} for the various radiative decay channels and the Γ_{fit1}, Γ_{fit2}, Γ_{fit3}, Γ_{fit4} and Γ_{fit5} predictions from the enhanced model associated to the fit values from Eqs. (13), (14), (15), (16), and (17), respectively.

Transition	Γ_{exp} (keV)	Γ_{fit1} (keV)	Γ_{fit2} (keV)	Γ_{fit3} (keV)	Γ_{fit4} (keV)	Γ_{fit5} (keV)
$\rho^0 \to \eta\gamma$	44 ± 3	41 ± 3	41 ± 3	38 ± 2	38 ± 2	41 ± 3
$\rho^0 \to \pi^0\gamma$	69 ± 9	85 ± 5	85 ± 5	82 ± 2	79 ± 2	85 ± 5
$\rho^+ \to \pi^+\gamma$	67 ± 7	67 ± 8	74 ± 2	75 ± 2	75 ± 2	74 ± 2
$\omega \to \eta\gamma$	3.8 ± 0.3	4.0 ± 0.5	4.0 ± 0.5	3.4 ± 0.2	3.5 ± 0.2	4.0 ± 0.5
$\omega \to \pi^0\gamma$	713 ± 20	705 ± 21	701 ± 20	703 ± 19	704 ± 19	701 ± 20
$\phi \to \eta\gamma$	55.4 ± 1.1	55 ± 3	55 ± 8	54 ± 8	54 ± 8	55 ± 3
$\phi \to \eta'\gamma$	0.26 ± 0.01	0.27 ± 0.01	0.27 ± 0.04	0.28 ± 0.05	0.27 ± 0.05	0.27 ± 0.01
$\phi \to \pi^0\gamma$	5.5 ± 0.2	5.5 ± 1.0	5.5 ± 1.1	5.5 ± 0.3	5.5 ± 0.3	5.5 ± 1.0
$\eta' \to \rho^0\gamma$	57 ± 3	57 ± 4	57 ± 4	56 ± 3	55 ± 3	57 ± 4
$\eta' \to \omega\gamma$	5.1 ± 0.3	5.2 ± 0.2	5.2 ± 0.2	6.4 ± 0.1	6.5 ± 0.1	5.2 ± 0.2
$K^{*0} \to K^0\gamma$	116 ± 10	116 ± 11	116 ± 10	116 ± 10	116 ± 10	-
$K^{*+} \to K^+\gamma$	46 ± 4	46 ± 5	46 ± 5	46 ± 5	46 ± 5	-
χ^2_{min}/d.o.f.	-	2.3	1.9	4.4	4.8	1.9

PHYSICAL REVIEW D **101,** 014027 (2020)

Radiative decays in charmonium beyond the p/m approximation

R. Bruschini* and P. González†

- *Radiative decays can test different quark models.*
- *In charmonium p/m approximation is not a good approximation and a better approximation in terms of masses and photon momentum can be implemented*
- *The long wave approximation can not give accurate results*
- *For bottomonium the difference is around 15%*

TABLE IV. Experimental values of the photon energy $|\boldsymbol{k}|_{\text{Expt}}$ and calculated values of $|\boldsymbol{k}|_{\text{Expt}}(2\langle r^2\rangle^{\frac{1}{2}})_{^3P_J}$ from Model II for $^3S_1 \to \gamma^3P_J$ and $^3P_J \to \gamma^3S_1$ radiative transitions.

$^3S_1 \to \gamma^3P_J$	$\lvert\boldsymbol{k}\rvert_{\text{Expt}}$ (MeV)	$\lvert\boldsymbol{k}\rvert_{\text{Expt}}(2\langle r^2\rangle^{\frac{1}{2}})_{^3P_J}$
$\psi(2S) \to \gamma\chi_{c_0}(1p)$	261	1.6
$\psi(2S) \to \gamma\chi_{c_1}(1p)$	171	1.0
$\psi(2S) \to \gamma\chi_{c_2}(1p)$	128	0.8
$\chi_{c_0}(1p) \to \gamma J/\psi$	303	1.2
$\chi_{c_1}(1p) \to \gamma J/\psi$	389	1.5
$\chi_{c_2}(1p) \to \gamma J/\psi$	430	1.6

Radiative Decay	$(\Gamma^{(\text{Theor-Expt})}_{\text{LWL}})_I$ (KeV)	$(\Gamma^{(\text{Theor-Expt})}_{p/M})_I$ (KeV)	$\Gamma^{PDG}_{\text{Expt}}$ (KeV)	$(\Gamma^{(\text{Theor-Expt})}_{p/M})_{II}$ (KeV)	$(\Gamma^{(\text{Theor-Expt})}_{\text{LWL}})_{II}$ (KeV)
$\psi(2S) \to \gamma\chi_{c_0}(1p)$	61	77	28.8 ± 1.4	57	47
$\psi(2S) \to \gamma\chi_{c_1}(1p)$	53	52	28.7 ± 1.5	41	41
$\psi(2S) \to \gamma\chi_{c_2}(1p)$	37	37	28.0 ± 1.3	29	29
$\chi_{c_0}(1p) \to \gamma J/\psi$	186	160	151 ± 14	118	128
$\chi_{c_1}(1p) \to \gamma J/\psi$	386	464	288 ± 22	315	266
$\chi_{c_2}(1p) \to \gamma J/\psi$	513	616	374 ± 27	419	353

TABLE VII. Predicted widths from Model II. Same notation as in Table VI. $\Gamma^{(\text{Theor-Expt})}_{\text{complete}}$: calculated width implemented with the experimental masses and photon energy. The errors correspond to the estimated maximum uncertainties.

Radiative Decay	$(\Gamma^{(\text{Theor-Expt})}_{\text{complete}})_{II}$ (KeV)
$\chi_{c2}(3930) \to \gamma J/\psi$	54 ± 27
$\chi_{c2}(3930) \to \gamma\psi(2S)$	128 ± 64
$\chi_{c0}(3860) \to \gamma J/\psi$	36 ± 18
$\chi_{c0}(3860) \to \gamma\psi(2S)$	45 ± 23

Radiative Decay	$(\Gamma^{(\text{Theor-Expt})}_{\text{complete}})_I$ (KeV)	$\Gamma^{PDG}_{\text{Expt}}$ (KeV)	$(\Gamma^{(\text{Theor-Expt})}_{\text{complete}})_{II}$ (KeV)
$\psi(2S) \to \gamma\chi_{c_0}(1p)$	54	28.8 ± 1.4	43
$\psi(2S) \to \gamma\chi_{c_1}(1p)$	35	28.7 ± 1.5	30
$\psi(2S) \to \gamma\chi_{c_2}(1p)$	20	28.0 ± 1.3	18
$\chi_{c_0}(1p) \to \gamma J/\psi$	187	151 ± 14	130
$\chi_{c_1}(1p) \to \gamma J/\psi$	415	288 ± 22	284
$\chi_{c_2}(1p) \to \gamma J/\psi$	566	374 ± 27	385

PHYSICAL REVIEW D **103**, 074029 (2021)

BESIII Phys. Rev. Lett. 126, 102001 (2021)

Strange molecular partners of the $Z_c(3900)$ and $Z_c(4020)$

Zhi Yang[1,*] Xu Cao[2,3,†] Feng-Kun Guo[4,3,‡] Juan Nieves[5,§] and Manuel Pavon Valderrama[6,¶]

- *EFT framework using SU(3) flavor symmetry*
- *The mass does not necessarily coincide with BW*
- *Zcs could be a virtual state or a resonance*
- *Zcs is probably the SU(3) flavor partner of Zc(3900)*
- *Zcs* should exist as its spin partner*

Observation of a Near-Threshold Structure in the K^+ Recoil-Mass Spectra in $e^+e^- \to K^+(D_s^- D^{*0} + D_s^{*-} D^0)$

$$M_{Z_{cs}}^{pole} = (3982.5^{+1.8}_{-2.6} \pm 2.1)\ \mathrm{MeV}/c^2,$$

$$\Gamma_{Z_{cs}}^{pole} = (12.8^{+5.3}_{-4.4} \pm 3.0)\ \mathrm{MeV},$$

Close to threshold

Potential	States	Thresholds	Masses ($\Lambda = 0.5$ GeV)	Masses ($\Lambda = 1$ GeV)	Experiment [4,12]
$V^{(O)}_{\mathrm{virtual}}$	$\frac{1}{\sqrt{2}}(D\bar{D}^* - D^*\bar{D})$	3875.8	Input [23]	Input [23]	$3888.4 \pm 2.5 - i(14.2 \pm 1.3)$
[Eq. (14)]	$D^*\bar{D}^*$	4017.2	3988^{+21}_{-27}	3978^{+25}_{-36}	$4024.1 \pm 1.9 - i(6.5 \pm 2.5)$
	$D\bar{D}_s^*/D^*\bar{D}_s$	3979.4/3976.9	3948^{+22}_{-27}	3937^{+25}_{-36}	
	$D^*\bar{D}_s^*$	4120.8	4092^{+21}_{-26}	4083^{+24}_{-35}	
$V^{(O)}_{\mathrm{res}}$	$\frac{1}{\sqrt{2}}(D\bar{D}^* - D^*\bar{D})$	3875.8	Input [23]	Input [23]	$3888.4 \pm 2.5 - i(14.2 \pm 1.3)$
[Eq. (15)]	$D^*\bar{D}^*$	4017.2	$4025 \pm 4 - i(21 \pm 7)$	$4035 \pm 6 - i(29 \pm 13)$	$4024.1 \pm 1.9 - i(6.5 \pm 2.5)$
	$D\bar{D}_s^*/D^*\bar{D}_s$	3979.4/3976.9	$3986 \pm 4 - i(22 \pm 7)$	$3996 \pm 6 - i(30 \pm 13)$	$3982.5^{+2.8}_{-3.3} - i(6.4^{+3.0}_{-2.7})$
	$D^*\bar{D}_s^*$	4120.8	$4129 \pm 4 - i(21 \pm 7)$	$4138 \pm 6 - i(28 \pm 12)$	
$V^{(O)}_{\mathrm{virtual}}$	$\frac{1}{\sqrt{2}}(D\bar{D}^* - D^*\bar{D})$	3875.8	3871^{+2}_{-3}	3867^{+4}_{-7}	$3888.4 \pm 2.5 - i(14.2 \pm 1.3)$
[fit I, Eq. (16)]	$D^*\bar{D}^*$	4017.2	4014^{+2}_{-3}	4012^{+3}_{-6}	$4024.1 \pm 1.9 - i(6.5 \pm 2.5)$
	$D\bar{D}_s^*/D^*\bar{D}_s$	3979.4/3976.9	3974^{+2}_{-3}	3971^{+3}_{-6}	
	$D^*\bar{D}_s^*$	4120.8	4117^{+3}_{-5}	4115^{+3}_{-6}	
$V^{(O)}_{\mathrm{res}}$	$\frac{1}{\sqrt{2}}(D\bar{D}^* - D^*\bar{D})$	3875.8	$3861^{+15}_{-5} - i6^{+11}_{-6}$ (R/V)	$3861^{+16}_{-29} - i0^{+34}_{-0}$ (R/V)	$3888.4 \pm 2.5 - i(14.2 \pm 1.3)$
[fit II, Eq. (17)]	$D^*\bar{D}^*$	4017.2	$4004^{+14}_{-6} - i0^{+15}_{-0}$ (R/V)	$4006^{+11}_{-32} - i0^{+30}_{-0}$ (R/V)	$4024.1 \pm 1.9 - i(6.5 \pm 2.5)$
	$D\bar{D}_s^*/D^*\bar{D}_s$	3979.4/3976.9	$3963^{+15}_{-5} - i3^{+17}_{-3}$ (R/V)	$3966^{+13}_{-31} - i0^{+31}_{-0}$ (R/V)	$3982.5^{+2.8}_{-3.3} - i(6.4^{+3.0}_{-2.7})$
	$D^*\bar{D}_s^*$	4120.8	$4110^{+11}_{-5} - i0^{+15}_{-0}$ (R/V)	$4111^{+10}_{-23} - i0^{+28}_{-0}$ (R/V)	

*Fitting Zc and Zc**

Fitting BESSIII data

Physics Letters B 818 (2021) 136382

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BESIII Phys. Rev. Lett. 126, 102001 (2021)

The strange partner of the Z_c structures in a coupled-channels model

Pablo G. Ortega [a,*], David R. Entem [b], Francisco Fernández [b]

Observation of a Near-Threshold Structure in the K^+ Recoil-Mass Spectra in $e^+e^- \to K^+(D_s^- D^{*0} + D_s^{*-} D^0)$

$$M^{pole}_{Z_{cs}} = (3982.5^{+1.8}_{-2.6} \pm 2.1)\ \text{MeV}/c^2,$$

$$\Gamma^{pole}_{Z_{cs}} = (12.8^{+5.3}_{-4.4} \pm 3.0)\ \text{MeV},$$

Close to threshold

- *Coupled-channel calculation in the CQM*
- *Production amplitude fitted to data*
- *Two models (with and without annihilation diagrams)*
- *χ2 of 1 for BESIII and 2-2.6 for LHCb data*
- *Two virtual states:*
  - *3970 and 3961-3i analog to the Zc(3900)*
  - *4110 and 4106-5i analog to the Zc(4020)*

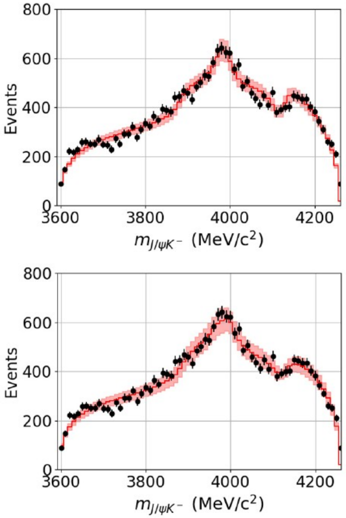

Fig. 3. Theoretical description (solid) of the experimental $J/\psi K^-$ invariant mass spectrum (black dots) measured by LHCb [21]. Same legend as in Fig. 2.

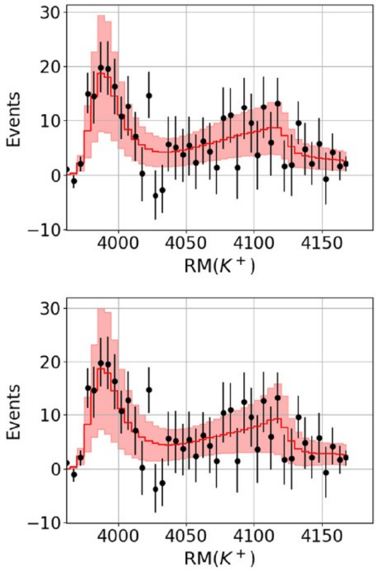

Fig. 2. Theoretical description (solid lines) of the experimental K^+ recoil-mass spectra (black dots) measured by BESIII [6]. The red shadowed-area around the line represents the 68% CL of the fit. The upper panel shows the calculation for *model a* and the lower panel for *model b*. We remark here that the fit only affects the production part from the e^+e^- vertex, with no fine-tuning of the CQM parameters in the description of the coupled-channels S-matrix.

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Editors' Suggestion

Observation of New Resonances Decaying to $J/\psi K^+$ and $J/\psi\phi$

R. Aaij et al.*
(LHCb Collaboration)

$Z_{cs}(4000)$	15 (16)	$4003 \pm 6^{+4}_{-14}$	$131 \pm 15 \pm 26$	$9.4 \pm 2.1 \pm 3.4$
$Z_{cs}(4220)$	5.9 (8.4)	$4216 \pm 24^{+43}_{-30}$	$233 \pm 52^{+97}_{-73}$	$10 \pm 4^{+10}_{-7}$

symmetry MDPI

Article

Symmetries, Partners and Thresholds: The Case of the X_b

Pablo G. Ortega [1,†], David R. Entem [2,*,†] and Francisco Fernández [3,†]

Bottom partner of the X(3872)

- Coupled-channel calculation in the CQM mixing one and two meson channels.
- The coupling can change HQS and HFS expectations
- There is a possible partner of the X(3872)
- Isospin breaking effects are smaller

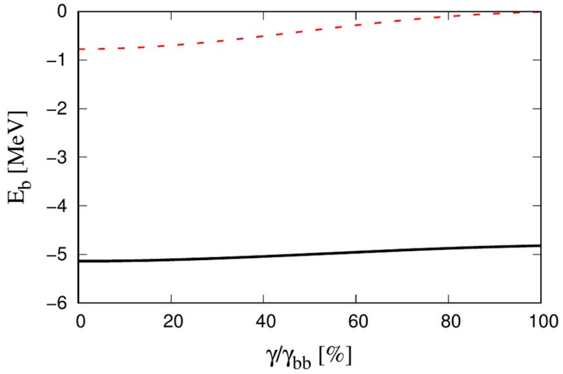

Figure 5. Binding energy of the bottom partner of the $X(3872)$ as a function of the ${}^3P_0$ strength constant γ, expressed in % with respect to the $b\bar{b}$ sector value of $\gamma_{bb} = 0.205$. The black-solid line shows the full coupled-channels calculation including $B\bar{B}^* + B^*\bar{B}^* + \Upsilon(2S)\omega$, whereas the red-dashed shows the binding energy only including the $B\bar{B}^*$ channel.

Table 4. Dressed $b\bar{b}$ and additional states for $J^{PC} = 1^{++}$.

	State 1		State 2		State 3		State 4	
Mass [MeV]	10,471.9		10,599.3		10,738.8		10,759.5	
Width [MeV]	0		0.51		0.56		13.51	
	$\mathcal{P}$[%]	Γ [MeV]	$\mathcal{P}$[%]	Γ [MeV]	$\mathcal{P}$[%]	Γ [MeV]	$\mathcal{P}$[%]	Γ [MeV]
$b\bar{b}(3^3P_1)$	88.70	–	0.33	–	0.08	–	2.97	–
$b\bar{b}(4^3P_1)$	0.02	–	0.14	–	0.96	–	11.82	–
$B\bar{B}^*$	6.26	0	93.65	0	20.01	0.47	48.09	4.30
$B^*\bar{B}^*$	5.02	0	5.84	0	78.94	0.07	37.02	4.30
$\Upsilon(2S)\omega$	0.00	0	0.04	0	0.003	0	0.002	0
$\Upsilon(1S)\omega$	–	5×10^{-4}	–	0.51	–	0.015	–	4.91

BB* ***B*B****

Table 5. Dressed $b\bar{b}$ states and additional for $J^{PC} = 2^{++}$.

	State 1		State 2		State 3		State 4		State 5	
Mass [MeV]	10,485.2		10,551.6		10,685.6		10,766.9		10,768.3	
Width [MeV]	0		0		32.19		13.3		65.48	
	$\mathcal{P}$[%]	Γ [MeV]	$\mathcal{P}$[%]	Γ [MeV]	$\mathcal{P}$[%]	Γ [MeV]	$\mathcal{P}$[%]	Γ [MeV]	$\mathcal{P}$[%]	Γ [MeV]
$b\bar{b}(3^3P_2)$	88.56	–	1.14	–	0.26	–	0.46	–	2.39	–
$b\bar{b}(2^3F_2)$	0.50	–	83.59	–	3.02	–	0.13	–	0.07	–
$b\bar{b}(4^3P_2)$	0.02	–	0.01	–	23.00	–	3.66	–	15.93	–
$b\bar{b}(3^3F_2)$	0.00	–	0.05	–	6.05	–	33.91	–	17.79	–
$B\bar{B}$	2.87	0	10.92	0	13.47	4.49	21.21	4.52	17.32	37.3
$B\bar{B}^*$	1.83	0	3.08	0	4.57	14.97	12.93	4.05	2.42	2.88
$B^*\bar{B}^*$	6.23	0	1.22	0	49.57	12.62	27.68	4.12	44.05	25.25
$\Upsilon(2S)\omega$	0.00	0	0.00	0	0.05	0.00	0.01	0	0.03	0.00
$\Upsilon(1S)\omega$	–	0	–	0	–	0.11	–	0.61	–	0.05

B*B*

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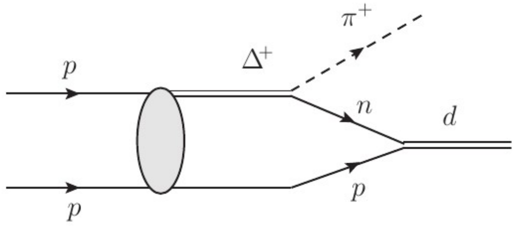
Triangle singularity mechanism for the $pp \to \pi^+ d$ fusion reaction

Natsumi Ikeno,[1,2,*] Raquel Molina,[2,†] and Eulogio Oset[2,‡]



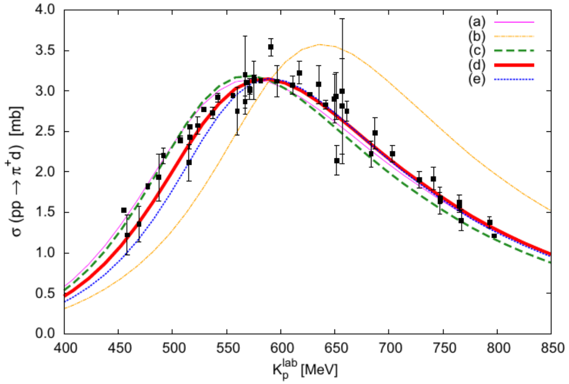
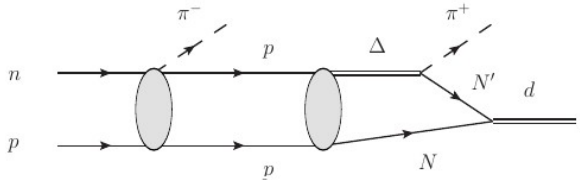


FIG. 6. Cross section of $pp \to \pi^+ d$ as a function of the kinetic energy in the laboratory frame of the proton. The variable s is $s = 4M_N^2 + 2M_N K_p^{\rm lab}$.

Sequential single pion production explaning the dibaryon "$d^*(2380)$" peak

R. Molina,[1,*] Natsumi Ikeno,[1,2,†] and Eulogio Oset[1,‡]

arXiv:2102.05575v3 [nucl-th] 3 Mar 2021



HaSp-STRONG2020 Workshop

Thank you for your attention